CHAPTER 2: LITERATURE REVIEW

This chapter makes a survey of the literature on evaluating environmental regulation, with emphasis on guidance relevant to the current Superfund Benefits Analysis (SBA) [this report]. In particular, the chapter focuses on literature that addresses the benefits of Superfund or provides important insights into understanding the SBA. The several sections of this chapter address the evaluation of environmental regulation, health risks, ecological risks, previous studies of the overall Superfund program, and emergent themes. Subsequent chapters contain further reviews of topical and methodological literature as required (for instance, Chapter 5 reviews the literature on property-based price analysis).[1]

Evaluating Environmental Regulation

EPA's Regulatory Policy Council, Science Advisory Board, and National Center for Environmental Economics (NCEE), as well as the Office of Management and Budget (OMB)—specifically the Office of Information and Regulatory Affairs (OIRA)—have provided clear, and in the case of OIRA, authoritative guidance for regulatory analysis in support of rulemaking. The intellectual foundations for this guidance can be found in the literature on public health, welfare and environmental economics, risk assessment, and related topics (e.g., Arrow and Fisher 1974; Sen 1982; Slovic 1987; Morgan and Henrion 1990; d'Arge 1993; Freeman 1993; Arrow et al. 1996; Bockstael et al. 2000; Arrow et al. 2000; Hammitt 2000; Paustenbach 2002). While the SBA is a retrospective analysis and not a rulemaking, effort has been made to be consistent with the established standards and to rely on the above foundations. This chapter addresses how the above guidance applies to the central question of the SBA: "What are the benefits of the Superfund program?"

The relevant EPA and OMB guidance generally anticipates a prospective study of new regulations, not a retrospective evaluation (President of the United States 1993; Office of Information and Regulatory Affairs and Council of Economic Advisors 1996; U.S. Environmental Protection Agency 2000; Office of Management and Budget 2003a). However, the approach of prospective versus retrospective does not alter the fundamentals of good regulatory analysis, including objectivity, reliable theoretical foundations, suitable data, clarity of explanation (transparency), adequate treatment of uncertainty, and completeness (Morgan and Henrion 1990). One important exception is that the EPA and OMB guidance requires that alternative modes of regulation be considered; there is no point in doing so in a retrospective analysis. Thus, the SBA analyzes the benefits of the existing Superfund program and compares these to a single scenario that assumes there is no Superfund program (see Chapter 1).

Executive Order 12866 and related guidance provide important and authoritative guidance for regulatory analyses, and thus are relevant to the SBA (President of the United States 1993; Office of Information and Regulatory Affairs and Council of Economic Advisors 1996; President of the United States 2002; Office of Management and Budget 2003a). The portions of this Executive Order relevant to the SBA are described in Section 1, parts (a), (b)(1), (b)(4), (b)(6), (b)(7), and (b)(9). These portions require: identifying the problem; considering the risks of

[1] For simplicity, terms like "property-based valuation" are used in this study to refer to analyses that rely on hedonic price theory (Taylor 2003).

various substances; assessing the benefits, using reasonably obtainable scientific, technical, economic, and other information; and paying appropriate attention to state, local, and tribal views. The remainder of the Executive Order addresses the form of regulation selected, which is irrelevant for a retrospective analysis.

The OMB's *Best Practices Guidances* and *Circular A-4* provide explicit guidance on numerous issues that are at the heart of regulatory analysis and that reflect the intent of Executive Order 12866 (Office of Management and Budget 2003; Office of Information and Regulatory Affairs and Council of Economic Advisors 1996). Many of the principles and practices identified by the OMB have been included in EPA's guidance, which was rated as "excellent" by the Science Advisory Board (U.S. Environmental Protection Agency 2000 p. A-1).

The SBA conforms to the guidance in the following ways. Chapter 1 of the SBA describes the need for Superfund, which is due to both externalities and a lack of incentives for producing the information or technologies needed to adequately manage uncontrolled releases of hazardous substances. Chapter 1 also describes the baseline for the SBA.

The SBA considers benefits created by all actions taken under the Superfund program from 1980-2004, using discount rates of 3% and 7% where discounting is appropriate, and discusses the possible implications of intergenerational effects where these are appropriate. All of the chapters that include quantitative information include discussions of risk and uncertainty, as well as discussions of the assumptions underlying the analysis. Non-monetized benefits are described, and where possible they are quantified.

The structure of this analysis, as described in Chapter 1, follows the *EPA Guidelines for Preparing Economic Analyses (EPA Guidelines),* including the use of effect-by-effect and benefits transfer analyses (U.S. Environmental Protection Agency 2000). In addition, the SBA follows the *EPA Guidelines* in the use of specific techniques. These include revealed preference methods such as property-based price studies and cost of illness analyses to estimate the benefit of reduced incidence of disease, and EPA's recommended value of a statistical life ($6.1 million (2000$)).[2] Chapters 4 and 5 describe the methods used for each benefit in detail, referring to the general guidance discussed above as well as more specific guidance as appropriate (e.g., U.S. Environmental Protection Agency 2002). Chapter 10 of the *EPA Guidelines* provides guidance on presenting the results of economic analyses and also helped shape the SBA.

The methods employed in Chapters 4 and 5 are used to develop estimates of the monetary value of using benefits transfer methods, which *Circular A-4* indicates should be avoided under some conditions. These cases include the evaluation of unique attributes, the use of *ex ante* data, and the use of data from cases with significantly different magnitudes than the case to which the data are being applied. None of these conditions holds here. Another key issue for benefits transfer analysis is to ensure the demographics and market sizes of the study cases and policy case are similar. The analyses in Chapters 4 and 5 meet this requirement because they are conducted at the level of individual sites, and then aggregated. Thus, for instance, the analysis treats the housing market as a set of local markets, not as a national market.

[2] Note that the sections in which this is relevant (in Chapter 5) have not been completed due to prior agreement with the EPA's Science Advisory Board. Thus, this value is not actually used in this draft.

Although it is not guidance, the recent *Benefits and Costs of the Clean Air Act (Clean Air Act)* study is a very useful reference since it shares many features of the SBA (U.S. Environmental Protection Agency 1997). Its structure and content influenced the SBA's analysis of the Superfund program. Critiques of the *Clean Air Act* study also offered useful insights, especially that aggregation of large environmental programs can be less useful than detailed treatment of individual parts when it is possible to take this approach (Krupnick and Morgenstern 2002; Freeman 2002). This insight, for instance, emphasizes that the individual quantitative estimates of benefits found in Chapters 4 and 5 should be kept separate.

Understanding the Health Risks of Hazardous Substances

Reducing human health risk is among the most important benefits of the Superfund program and there is a vast literature on the subject, including several major reviews that have been completed in the last several years. This section briefly discusses three of these reviews, leaving more detailed discussion of the literature to Chapter 5.

An appropriate starting place is a 1991 review by the National Research Council (NRC), which reviewed then-current knowledge of the human health effects caused by exposure to hazardous substances in the environment (National Research Council 1991). The NRC concluded that despite poor data "the committee does find sufficient evidence that hazardous wastes have produced serious health effects in some populations" but that the data then available made it impossible to determine the effect of regulation (National Research Council 1991, 19-21).

The NRC panel noted that studies of specific sites have documented symptoms of ill health, including low birth weight, birth defects such as cardiac anomalies, and a variety of neurobehavioral problems. Health problems with long latency periods are more difficult to detect, but some of the studies reviewed by the NRC detected increased incidence of cancer in people exposed to compounds similar to those that occur at hazardous waste sites. In addition, it appeared that risks to future populations might be larger than current risks, mostly due to ground water exposure routes: "Although current risks could be negligible, studies show that millions of tons of hazardous materials are slowly migrating into ground water in areas where they could pose problems in the future" (National Research Council 1991, 259).

The level of potential exposure to contaminated ground water found by the NRC was high:

> In 1984 an evaluation of 93 sites on the California Department of Health State Superfund list showed … 46 of the sites showed evidence of waste release into ground water, and in 34 of these cases the ground water was known to be used for drinking. Extensive or systematic sampling occurred in only 22 of the sites, despite the evidence of potential contamination … Moreover, in all of the sites where there was known contamination of ground water, more than 10,000 persons were potentially exposed. (259)

The NRC panel noted that serious health effects have occurred at some hazardous waste sites, that hazardous waste abounds in the U.S., and that people live and work in close proximity to some of this waste (National Research Council 1991, 1-2). However, the NRC panel are quick to point out that proximity to hazardous waste does not necessarily imply exposure and health risk, only that the potential for exposure is increased. Perhaps the most important gap was in exposure data, which the NRC felt had received inadequate support. The data that are available tend to "reflect data requirements of environmental engineering and site remediation, rather than public health considerations" (National Research Council 1991, 142).

Several features of the NRC study are worth noting, including an exclusive focus on National Priorities List (NPL) sites, an emphasis on ground water contamination, and an emphasis on the risks to future generations. Another key feature is the poor quality of exposure data that are readily accessible to researchers, which limits their ability to determine causal linkages between hazardous wastes at sites and negative health outcomes (National Research Council 1991, 101-153). Importantly, a wide array of health outcomes were examined in the studies reviewed by the NRC, including damage to the nervous system, cancer, birth defects, and a host of lesser symptoms (e.g., eye irritation, fatigue).

A second review covers much of the research published up to 1998 on the health effects of hazardous substances, including over 450 journal articles, books, reports, and other sources (Johnson 1999a). Some parts of this volume had appeared previously in the peer-reviewed literature (e.g., Johnson 1995, 1999b; Johnson and DeRosa 1995). A significant portion of this research was conducted by (or for) the Agency for Toxic Substances and Disease Registry (ATSDR), the Superfund Basic Research Program (SBRP), and EPA's Office of Research and Development (ORD). A former director of ATSDR is the author of the 1999 review.

Johnson documents the widespread *potential* for exposure to hazardous wastes using data and methods that are better than those available to the researchers in the 1991 NRC report (Johnson 1999a, 41-73). At NPL sites the ATSDR examines, completed exposure pathways are common. Two percent of these sites present an "urgent hazard," 21% present a "hazard," and the remainder are less hazardous or not at all (Johnson 1999a, 33). Most of these sites indicate a need for action to reduce ongoing exposure pathways (Johnson 1999a, 38). The chemicals that are most frequently found with completed exposure pathways are lead, arsenic, benzene, trichloroethylene, mercury, and cadmium. Combinations of these chemicals are also frequently seen. (For updates, see Agency for Toxic Substances and Disease Registry 2003a; 2003b.)

These studies tend to understate the total risk of a site as it was originally discovered because the Public Health Advisories (PHAs) that ATSDR performs are generally conducted after removal actions designed to mitigate imminent risk to the public are complete (see Chapter 3 for a definition and discussion). Thus, PHAs will only evaluate the residual risk. Evaluation of residual risk is appropriate for making further decisions about improving public health at a site but tends to underestimate the total risk originally presented by the site, and is an example of the problems associated with data collection identified by the NRC panel above. Other studies have observed similar phenomena (e.g., Hamilton and Viscusi 1999a, 105-7, 231).

The survey of over 60 health studies in Johnson's review (Johnson 1999a) is the most relevant foundation for the SBA. Studies reviewed in this survey included both state-based surveillance programs and studies of individual hazardous waste sites. A few studies found no associations, but others showed associations between proximity to sites with hazardous substances and congenital malformations, especially birth defects of the heart, neural tube, and oral cleft palate, reduced birth weight, and decreased fertility. In general, these studies utilize better (but still very limited) data and improved methodologies compared to those reviewed by the NRC in 1991. Johnson's overall assessment is that:

> The most compelling health findings are those from studies of reproductive outcomes in populations living near certain kinds of hazardous waste sites. The weight of evidence associates select birth defects and reduced birth weight of infants born to parents who lived near sites. The release of VOCs into ground water seems a common factor in studies of increased rates of birth defects and lower birth weight. The birth defects most often reported are malformations of the heart, neural tube, and oral cleft palate. There is also troubling evidence that human fertility in adults can be reduced from exposure as children to high lead levels … The association between increased cancer rates and exposure to substances released from hazardous waste sites is less well documented than for reproductive outcomes. (196-199)

Johnson (1999a) also provides some data about uncontrolled chemical releases that lead to emergencies. These events present significant risks. For instance, in 14 states there were 5,502 such events in 1996, which led to 1,620 victims and 33 fatalities. Victims included employees, the public, and first responders.

Johnson (1999a, 201-218) also surveys studies of occupational risk associated with remediation of hazardous substances and finds very limited data. The existing information suggests that first responders, health care providers, waste disposal workers, and site remediation workers face no significant *health* risks due to their employment. However, one study based on average *safety* risk data for various trades (especially truck driver, laborer, oiler, and bulldozer operator) from the 1970s and early 1980s showed significant occupational risk of fatalities due to accidents during some types of site remediation.

The most recent review discussed in this section looks at five studies of the effect of drinking water contamination by solvents on birth defect rates and reported mixed evidence (Bove, Shim, and Zeitz 2002). The review found evidence of excess neural tube defects and of congenital cardiac abnormalities, but was limited by lack of exposure data. Because birth defects are relatively rare events, it is difficult to detect changes in their rate of incidence without very large population samples, which are typically not available. In addition, difficulties in estimating exposure are likely to result in misclassification biases that underestimate risk. Nonetheless, depending on the specific solvent, odds ratios for various serious birth defects (e.g., neural tube defects, fetal deaths) were found to have means well above 1.0 (with a range of 1.25 to 5.39).[3]

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[3] The odds of an event is the number of those who experience the event divided by the number of those who do not, and the odds ratio is simply the ratio of the odds in the two groups of interest. If the odds ratio is less than one, then the odds have decreased (and therefore so has the risk), but if the odds ratio is greater than one then the odds have increased. When the risks in the two groups being compared are both small (e.g., less than 20%) then the odds will approximate the risks, and the odds ratio will approximate the relative risk. The odds of any congenital malformation is less than 2% in the United States, and the odds of specific conditions is much lower than that (Anonymous 2003). Thus, odds ratios for birth defects closely approximate increased risks; an outcome with an odds ratio of 1.25 implies approximately a 25% increased risk.

However, scarce data yielded large confidence intervals that sometimes included 1.0. The review also found that studies often looked for confounding effects and generally found that factors such as smoking, alcohol consumption, maternal illness, socio-economic status, and demography had little influence.

Overall, these three reviews indicate there is lack of evidence about the health effects of uncontrolled releases of hazardous substances, although there is relatively more evidence for increased rates of congenital malformations than for cancer or other diseases. The major problem is a lack of accessible high-quality exposure data, which is a widely recognized problem (Harrison 2003). Studies published after the periods covered by these three reviews are discussed in Chapter 5, and although some of these find stronger statistical associations, the lack of exposure data persists. Furthermore, it is not clear if this problem is likely to be solved, especially for historical exposures. While dose reconstruction may be possible for some substances (e.g., lead), the lack of long-term indicators and data about past ambient concentrations and activity levels diminish the prospects for reliable estimates of past exposures.

Understanding the Ecological Risks of Hazardous Substances

Ecological risk assessment has become a more well-understood and more widely-practiced activity in the last decade (Suter et al. 2000). EPA's guidelines require that ecological risk assessments (ERAs) be conducted at every site at which there is a response action (i.e., a remedial or removal action) according to a well-established, consistent process (Luftig 1999; U.S. Environmental Protection Agency 1998). However, ecological risks play a relatively small role in determining the directions of Superfund responses, compared to health risks (Walker, Sadowitz, and Graham 1995, 29; Suter et al. 2000, Chapter 8). Further, the problems of lack of accessibility and inappropriate assumptions for a benefits estimation that plague health risk assessments of Superfund sites also apply to ERAs.

The growing literature on ecological risk tends to be in biology, toxicology, and similar fields, while there is relatively little literature on the economics of these issues (Barnthouse and Stahl 2002). The current economics-oriented literature focuses on the concept of natural resource damages, which are closely related to the natural resource provisions of CERCLA (Kopp 1989; Dunford 2000; Stopher 2000; Reisch 2001; Morey 2002; Damage Assessment and Restoration Program 2004). In particular, there is a lack of economic analysis of potential ecological improvements due to response actions. Searches in the published and gray literature for quantitative estimates of the ecological risks addressed by Superfund responses yielded no results.[4]

Previous Analyses of the Benefits of the Superfund Program

This section reviews the numerous prior studies that have evaluated benefits of the Superfund program or that provide insight into how to evaluate these benefits. In some cases, detailed literature reviews are deferred until relevant sections of the report (e.g., Chapter 4 contains a detailed review of evaluation methods that rely on real estate sales data). Four studies are discussed in some detail (Hamilton and Viscusi 1995; Walker, Sadowitz, and Graham 1995; Hamilton and Viscusi 1999a; Probst and Konisky 2001) and several others are mentioned briefly.

[4] This search included the use of multiple electronic tools including online search engines, EPA's Web sites, and various databases such as EconLit and Web of Knowledge.

Finally, two proposed studies of closely related efforts under the Resource Conservation and Recovery Act (RCRA) and comments on these proposals by the Science Advisory Board are reviewed (EPA Science Advisory Board 2002; Office of Solid Waste and Emergency Response 2000a, 2000b).

The most recent large study of Superfund contains an overview of the Superfund program and provides insight to understanding its benefits (Probst and Konisky 2001). This study focuses on the NPL and cleanup of NPL sites, and provides considerable information about the character of various response actions. This information shows great variation in the character and sizes of various sites (Probst and Konisky 2001, 21, 22, 28-30, 39, 40, and 47). The heterogeneity among sites that Superfund addresses is a common issue. This study also stresses the importance of three other features of Superfund: the removal program, "NPL equivalent sites," and support activities. Each of these is discussed briefly below.

Probst and Konisky (2001) stress that the removal program, which addresses about four times as many sites as the NPL program, is potentially important in mitigating health risk. Of the approximately 315 removals that occurred each year during 1992-99 (Probst and Konisky 2001, 19), more than 90% are categorized as "time-critical" and the short descriptions of four such cases (Probst and Konisky 2001, 20-21) provide stark (qualitative) evidence of the severity and immediacy of the risks the removal program addresses. Further, the authors argue that under the Superfund Accelerated Cleanup Model (SACM), removals substitute for remediations at some sites (Probst and Konisky 2001, 24, 99).

Probst and Konisky (2001) also highlight the typically overlooked concept of "NPL equivalent sites" (or, "Superfund alternative sites") that are eligible for NPL listing (i.e., they have an HRS score greater than 28.5) but are not listed. Instead, "responsible parties perform cleanup under EPA enforcement authority and with EPA oversight" (Probst and Konisky 2001, 40). In some cases, NPL equivalent sites are included in state Superfund programs, but they never enter the NPL. Without the existence of the Superfund program, it is very likely that these sites would not be cleaned up, so any reduced health and ecological risks at these sites are a benefit of the Superfund program. However, it is not clear what fraction of the benefit should be assigned to the Superfund program. This issue is analyzed quantitatively in Chapter 3 of the SBA.

Probst and Konisky (2001, 107-120) also describe the importance of support activities and programs. These support activities include program staff, management, and support; program administration; and other programs and agencies. These activities and programs account for about one-third of the cost of the program and without them "it is simply not possible to have a national Superfund Program" (Probst and Konisky, 107). Most of these costs are for items such as rent, payroll, and benefits that do not directly produce benefits; others are for programs that have impacts other than health risk reductions at Superfund sites.

Several important prior studies looked in some detail at specific NPL sites, usually by examining the Record of Decision (ROD) for each site. This approach provides insight because it makes use of some of the "extensive documentation [that] is publicly available … for each site" but which is usually evaluated on a site-by-site basis only (Walker, Sadowitz, and Graham 1995, 25). For instance, the study by Walker et al. (1995) evaluated 148 RODs and found that 81% of the sites they examined had maximum cancer risks that exceeded EPA standards, and (to the surprise of the authors) that the non-cancer health risks also exceeded acceptable standards at 74% of the sites. However, these standards are designed to be protective of human health and are thus conservative (Viscusi, Hamilton, and Dockins 1997). Nonetheless, almost half of the sites had non-cancer risks ten times the EPA standard, and almost one-fifth had non-cancer risks one hundred times the EPA standard (Walker, Sadowitz, and Graham 1995, 31). To these researchers, "the magnitude of the hazard indices reported for the hazardous waste sites in the database suggests the need for better understanding of the potential for non-cancer health effects."

This study also stressed the importance of "environmental and welfare risks that sites pose in addition to current and future health risks … [including] the nonuse value of ground water, which includes the psychological comfort of knowing that ground water is clean.… One of the hidden yet worthy objectives of the program is to protect the quality of our nation's ground water for future yet unspecified uses by humans and nonhuman species" (Walker, Sadowitz, and Graham 1995, 49-50). Neither of these benefits (psychological comfort and future use) seems to have been quantified in any way in the literature. Note, however, that they may be part of the rationale for the application of "applicable or relevant and appropriate requirements" (ARARs) to NPL sites (for instance, the application of state drinking water standards to groundwater).

The only significant study to go beyond reviewing RODs collected data from Baseline Risk Assessments (see Chapter 3 of the SBA for a discussion of these assessments) and estimated reductions in adult cancer risk due to remedial actions at NPL sites, as well as the costs (Hamilton and Viscusi 1999a, 1999b). This study ignored removal actions, largely because it was focused on decisions associated with remedial actions at NPL sites (Hamilton and Viscusi 1999a, 105). Note, however, that this approach would likely create an underestimate of the total benefits of the Superfund program if removals reduce significant risk.

The Hamilton and Viscusi (1999) study evaluated non-cancer risks, finding that 125 of 150 NPL sites evaluated had hazard index values greater than the allowed standard of one (Table 2.10, p. 53).[5] However, as discussed below, these are conservative estimates; thus it may be illuminating to consider the number of sites that have hazard quotients more than ten times the standard (which is 78), or more than half of the NPL sites evaluated. Most of these risks are to future populations; counting only the current exposure pathways leaves only 17 sites with a hazard quotient of greater then ten. Non-cancer risks are ignored in most of the rest of their analysis, principally because of "the difficulty of comparing non-cancer risks across chemicals, since the adverse outcomes range from drowsiness to death" (Hamilton and Viscusi 1999a, 53). In addition, although hazard quotients are numbers, they are not quantitative estimates of risk. The authors note that, "in a full benefit-cost analysis, EPA decision makers would collect more information on the harms of non-cancer health effects" (Hamilton and Viscusi 1999a, 231). Nonetheless, this research highlights the great heterogeneity of risks found at NPL sites.

The most well-known result of the Hamilton and Viscusi (1999) study is that the benefits they examine are concentrated in a small number of sites, creating a very wide range of site-specific

[5] A hazard index is the sum of the hazard quotients. The hazard quotient is the ratio of the intake of a contaminant to the reference dose of the contaminant.

costs per cancer case avoided (see, for instance, Hamilton and Viscusi 1999a, Figure 2). This conclusion also points to the very large variety in the type and magnitude of risks found at NPL sites. They also analyze the use of conservative values in the risk assessments upon which RODs are based (Viscusi, Hamilton, and Dockins 1997). Specific parameters treated this way include ingestion rate, exposure duration, and contaminant concentration. Conservative (i.e., high) values are used for these risk parameters to protect the public, and especially vulnerable individuals, from errors in regulatory decisions (such as the standard to which a remedial action will clean up an NPL site) due to variability in risk estimates. However, the use of such conservative risk estimates, and values derived from them, will tend to overstate the mean (average) benefits of the regulatory decision.

In addition, because of the high variability of benefits and costs across different sites, mean values are not useful in describing a "typical" NPL site or for providing an estimate of the central tendency of the population of NPL sites. This is because a small number of sites have most of the benefits while most NPL sites have few benefits, when measured in this way. However, this distribution of benefits across NPL sites does not affect estimates of the aggregate benefit, which is the relevant value for the SBA. That is, when calculating the total benefit of all NPL sites, the fact that most of the benefits are found at only a few sites makes no difference. Hamilton and Viscusi (1999a) describe the issue as follows:

> Overall, at these 150 sites, $2.2 billion dollars (1993$) in current and planned remediation actions are slated to be expended to avert 731 cancer cases, which yields a mean cost per cancer case averted of $3 million for remediation actions at the sites. This indicates that on balance the program is cost-effective in the aggregate using a mean cost per cancer case avoided. Yet the analysis in previous sections indicates that both risks and costs are concentrated in a small number of sites, so averages may not be fully informative. The median cost per cancer case averted is $388 million, without factoring in cost growth. (18)

In order to be more informative, Hamilton and Viscusi (1999a) also present statistics to better describe these results (Hamilton and Viscusi 1999a, Figure 2 and Table 6). However, the results described in the paragraph above rely on assumptions that take the conservative risk and cost estimates found in RODs on their face value and thus are not reliable for considering the benefits of risk mitigation.

To correct for the effects of conservatism, Hamilton and Viscusi (1999) present results for two other cases. In the least conservative case (case three), mean values are used for contaminant concentration and intake rate, a ten-year latency period is assumed, a 3% discount rate is used, and historical growth rates in the cost of NPL sites are used. While these adjustments do not account for all of the conservatism in EPA's risk estimates, they address most of them. This suggests that the mean cost per cancer case averted in case three would be more useful in understanding the aggregate benefits of remedial actions at NPL sites than the values given above (which are for case one).

However, Hamilton and Viscusi (1999a) do not give the mean value for case three, only the median, which is extremely high at $7.2 billion. This value indicates that *most* NPL site remediations do not cost-effectively reduce cancer risk, but does *not* indicate whether, in aggregate, NPL site remediations are cost-beneficial, given the three assumptions. To investigate this issue requires estimating the mean value for case three. Unfortunately, Hamilton and Viscusi (1999a) do not present the information needed to make the needed calculation. Specifically, the cost for the NPL sites in case three is not given. These costs vary from those for the NPL sites in case one because only 99 of the original 150 NPL sites in case one had mean concentration data and could be included in case three.

Nonetheless, a mean value for case three can be roughly estimated given the values found by Hamilton and Viscusi (1999a). The first step is to divide the cost of the remedial actions at the 150 sites in case one ($2.2 billion) by the number of cancer cases avoided in case three (p. 204), which results in a value of about $11 million. The second step is to consider the number of sites in each case. If the distribution of costs for case one sites and case three sites is such that the 51 NPL sites that are included only in case one and not in case three contribute very little total costs, then the mean cost per cancer case avoided in case three is slightly under $11 million. If the two distributions are similar, then the mean cost per cancer case avoided in case three is slightly over $7 million. And if the distribution of costs for case one sites and case three sites is such that the 51 NPL sites that are included only in case one account for more than the average of total costs, then the mean cost per cancer case avoided in case three is less than $7 million.

Hamilton and Viscusi (1999a) compare mean and median values of cost per cancer case avoided to values for avoided mortality found in studies of risk in the workplace and in use by regulatory agencies. They find that, "cleanup efforts with a cost per case of cancer prevented in the general range of $6 million or even $10 million are generally in the range of reasonableness, whereas expenditures of $50 million, $1 billion or possibly more would be outside this range" (Hamilton and Viscusi 1999a, 118).

Thus, the data provided in the only comprehensive study of site-specific risk mitigation at NPL sites (Hamilton and Viscusi 1999a), suggest that, based on reasonable risk parameter estimates, the mean cost of adult cancer risk reduction for the average of all NPL sites is reasonable and close to the EPA's recommended value of a statistical life. This implies that, roughly speaking and in aggregate, the benefits of adult cancer risk reduction at NPL sites is about equal to costs. However, this is *not* true for most NPL sites—benefits and costs are distributed widely, so for most sites benefits are much less than costs, as suggested by the median values given above.

The Office of Solid Waste and Emergency Response (OSWER) developed a set of proposed methodologies for assessing the costs, benefits, and other attributes of two OSWER programs with some similarities to Superfund: the RCRA Subtitle C prevention and waste minimization program, and the Underground Storage Tank (UST) cleanup program (Office of Solid Waste and Emergency Response 2000a, 2000b). These reports did not characterize or quantify any of the measures that they proposed. In December 2002, the EPA's Science Advisory Board prepared an advisory report on these two OSWER proposals (EPA Science Advisory Board 2002). While there are similarities between these programs and Superfund, there are also dissimilarities. One key difference is that the two RCRA programs are narrower than the entire set of approaches established by CERCLA and SARA, which are being evaluated in the present study. Thus, although the overall approaches proposed in the OSWER reports are not suitable for this study, the proposals and comments provided a valuable input to the design and implementation of the current study.

The OSWER proposals included an "Attributes Matrix" that the Science Advisory Board felt "creates potential problems … by loading too many extra considerations onto the conceptual framework provided by EPA's *Guidelines for Preparing Economic Analyses* (*Guidelines)* and by introducing distinctions that are not useful to the analysis" (p. 1). However, the Board did provide a modified Attribute Matrix that went beyond the *Guidelines* framework (pp. 12-13). In this spirit, the concepts of approaches and benefit categories discussed in Chapter 1 of the current study were developed by adding to the original framework from the *Guidelines* in a limited way.

The UST study proposed to assess cancer risks of benzene using data from three contingent valuation studies of the value of groundwater cleanup. The Science Advisory Board noted that studying the cancer risks of benzene was a "reasonable simplification of the problem" but that "the three studies cited, and to our knowledge any existing contingent valuation groundwater research, should not be used as estimates of total value (or the subset of health benefits) for the UST program" (pp. 15-16). The Board also noted difficulties with using avoided cost measures to estimate this benefit. In the context of the current study, a simplification to consider the benefits of just one compound would likely be unacceptable, given the wide range of hazardous substances found at sites addressed by Superfund. The current study also proposes (in Chapter 5) a less ambitious approach to evaluating the benefits of groundwater protection and cleanup that is focused more on the quantification of the amount of groundwater protected and remediated. A method is also proposed in the current study for dealing with some of the problems with contingent valuation data noted by the Board.

The Board is particularly concerned with the use of available risk data for estimating the benefits of cleanup of both carcinogens and non-carcinogens (p. 17). The problem for most carcinogens is that the available risk data is the 95% upper confidence interval on cancer potency or cancer risk. For non-carcinogenic substances, the available data are in the form of Reference Doses and Reference Concentrations, which are not suitable for use in estimating health benefits. These risk characterizations may be appropriate for environmental regulatory purposes, but are not useful for estimating benefits. In the context of the current study, these concerns have led to the methodology proposed in Chapter 5 to utilize an epidemiology-based approach similar to one found in the peer-reviewed literature (Lybarger et al. 1998).

The OSWER proposals include several ideas for estimating ecological improvements, all using concepts and models from the physical sciences and engineering, such as "pathway modeling." The Science Advisory Board criticizes this approach because it "bears only a crude relation to the social benefits of the program" (EPA Science Advisory Board 2002, 17). The Board goes on to suggest that monetized benefit estimates are most appropriate, and to note that ecological benefits are highly idiosyncratic to local conditions. The Board suggests that "[d]etailed analysis of a small number of sites could yield defensible benefits estimates at a relatively high cost. But the transfer of such benefits to the universe of sites is, in our judgment, not defensible" (p. 18). The Board then recommends that EPA develop quantitative indicators of ecosystem service benefits, perhaps using geographical information systems, and integrating this data into a "contamination events avoided" analysis (pp. 18-19). The current study adopts these recommendations as much as possible. The natural resource damage assessments associated with certain provisions of CERCLA actually comprise detailed analyses of specific sites, and these are proposed to be investigated more fully (Breffle et al. 2005; Barnthouse and Stahl 2002). In addition, a limited attempt to transfer these benefits to other restoration activities is proposed. Further, these studies, which evaluate restoration activities, may provide some qualitative insight into the ecological benefits of response actions; however, it is *not* proposed to attempt to transfer any of these benefits quantitatively. Finally, the use of GIS modeling is proposed for evaluating the benefits of the cleanup of groundwater.

The OSWER proposal for the UST study includes the use of property-value data (i.e., results from hedonic price studies) to estimate the benefits of cleanup, an analysis very similar to the one described in Chapter 4 of the current study. The Science Advisory Board concluded that this approach could be used to develop a 'ball park' or order-of-magnitude estimate of benefits" as long as certain theoretical and data issues were dealt with satisfactorily (EPA Science Advisory Board 2002, 3). Chapter 4 discusses these issues in detail and shows how all of the necessary conditions to yield a reliable estimate have been met.

The Science Advisory Board (2002, p. 23) also made the following comment: "Our skepticism about the value of a retrospective analysis and its accuracy (given the difficulty of any certainty about the without RCRA counterfactual) make us discourage a large commitment of resources to this exercise. As a result, we encourage the use of available data…" This recommendation has been followed in the design and implementation of the current study, as discussed in Chapters 3, 4, and 5.

Most recently, EPA published a study of the past accomplishments and future challenges of Superfund (U.S. Environmental Protection Agency 2004). One of the key challenges identified by this study is the backlog of NPL sites ready for long-term cleanup but for which there are inadequate resources. In particular, the study notes that, "the universe of Superfund sites [is] expanding in both number and type. Sites now entering the long term cleanup phase tend to be larger, require multiple remedies and are more complex than those originally placed on the NPL" (U.S. Environmental Protection Agency 2004, 9). This finding suggests that the heterogeneity of sites addressed by Superfund is growing.

General Themes Arising in the Literature

In addition to the detailed analyses presented above, there are a number of more general treatments of the Superfund program, including books, book chapters, and reports (e.g., Landy, Roberts, and Thomas 1994; Wildavsky 1995, Ch. 5; Andrews 1999; Nakamura and Church 2003; General Accounting Office 1999, 2003). This literature focuses almost entirely on the NPL. For instance, a fairly large group of studies has evaluated changes in the property values of residences near NPL sites in order to understand the benefits of remediation. Recent surveys of this literature indicate that there may be significant impacts of NPL sites on nearby home prices, but the magnitude of this effect can vary substantially from site to site (Farber 1998; Boyle and Kiel 2001). This literature is reviewed in detail in Chapter 4.

From the literature reviewed in this chapter, three key themes relevant to the SBA emerge: (i) the importance of the removal program, (ii) the heterogeneity of sites that Superfund has addressed, and (iii) the lack of adequate data to evaluate many of the benefits of Superfund.

The first major theme is that removal actions may account for a significant portion of the reduction in health risk. Many studies of the Superfund program do not mention the removal program at all, focusing instead on remediations at sites on the National Priorities List (NPL). Those that do consider the removal program make brief mention of it but are unanimous in finding that removals are a successful but poorly recognized part of the Superfund program. For instance, Hird (1994) identifies the removal program as the most important "hidden accomplishment" of the Superfund program, and quotes a former EPA Regional Office director, then in private industry, who "credits the removal action program for the fact that 'no site today poses an immediate health risk to the public'… despite the fact that final remediation was completed at fewer than four percent of the NPL sites" (Hird 1994, 29). Even harsh critics of the Superfund program believe the removal program is effective at reducing health risks (Wildavsky 1995, 183).

The second major theme is that releases of hazardous materials are highly heterogeneous and can pose a wide variety of risks. This is clearly a key message of the epidemiological reviews and site-specific risk analyses described above. The key implication is that sites at which the Superfund program takes an important role are likely to be quite heterogeneous as well. The case studies (one of which appears on the next page, and all of which are listed in Appendix B) provide an illustration of how different NPL sites are, and there is possibly even greater variety among response actions (see Table 3.2). The great variety of risks present at these sites suggests a corresponding variety of benefits from reducing or eliminating these risks.

The third theme is that there is a lack of adequate data with which to evaluate Superfund. Recognition of the third theme has led to the choice of approaches in Chapters 4 and 5, and to the extended narrative discussion of the non-quantified benefits in Chapter 6.

Case Study: Butterworth #2 Landfill

The Butterworth #2 Landfill Superfund site is located on approximately 180 acres within a primarily industrial area of Grand Rapids, Michigan.[1] It is also one of the study sites investigated by Hamilton and Viscusi (1999) and one of the property value study sites used in the analysis of Chapter 5. Kent County, which includes the city of Grand Rapids, is home to 13 Superfund National Priorities List (NPL) sites and over 590,000 people. The Butterworth #2 Landfill was operated by the city of Grand Rapids from 1950 until 1973, when the state of Michigan ordered that the landfill close due to improper operations. During operations, the Butterworth #2 Landfill accepted municipal and industrial wastes, including plating wastes, paint sludges, and organic solvents. The Butterworth #2 Landfill site was proposed to the NPL in 1982 and listed in 1983. At that time, the site was an environmental hazard due to an insufficient landfill cover allowing leachate to enter the adjacent Grand River.

Contaminants at the Butterworth #2 Landfill site include volatile organic compounds (VOCs) (such as benzene and vinyl chloride), polychlorinated biphenyls (PCBs), pesticides, and heavy metals (including arsenic and chromium) in site soils and the underlying aquifer. The site is "generally isolated from the public," and ground water is not currently used as a drinking water source. The ground water underlying the site discharges to the Grand River, but contaminants have not been detected in biota from the river.

During site investigations in 1988, EPA identified a hotspot of PCB and chromium contamination. A removal action was initiated to address this contamination and was completed in June 1990. In the baseline risk assessment for this site, EPA determined that if children were to play on the site they would be exposed to significant health risks even after the removal action is taken into account. The hazard index of non-cancer risks from exposure to contaminants in site soils (including VOCs, semi-volatile organic compounds (SVOCs), PCBs, and metals) was 13, compared to EPA's acceptable level of one.

The remedy selection process for this site is rather complex, and illustrates how the relevant federal and state agencies work together to deal effectively with landfill sites. The main challenge at many landfills is that they may have only a few hotspots that contain high concentrations of hazardous substances, while a large majority of the site is contaminated at lower levels, and some of the site is an uncontaminated buffer. The usual approach is to identify and then either remove or destroy the contaminants in the hotspot(s), and then to place a cap over the remainder of the contaminated portions of the site.

Butterworth #2 provides an example of how the federal and state governments work together to make difficult decisions about appropriate levels of remediation. The original remedy documented in the 1992 Record of Decision (ROD) called for capping the landfill and established alternate concentration limits (ACLs) for groundwater contaminants.[2] EPA proposed these ACLs because remediation to meet the applicable or relevant and appropriate requirements (ARARs) for this site (Michigan's water quality standards that had been established under the Michigan Water Resources Commission Act and the Michigan Environmental Response Act) would have been impracticable. However, the state of Michigan did not concur with this approach and sought more stringent cleanup.

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[1] Most of the information used to create this case study was obtained from various documents available on the internet in July 2004. These sources include: EPA's CERCLIS record of actions at the Butterworth #2 Landfill site; EPA's Explanation of Significant Differences for the Butterworth #2 Landfill site, October 23, 1998, www.epa.gov/superfund/sites/rods/fulltext/e0599138.pdf; EPA's NPL site fact sheet, updated January 2003, www.epa.gov/R5Super/npl/michigan/MID062222997.htm; EPA's NPL site listing narrative, December 1982, www.epa.gov/superfund/sites/npl/nar563.htm; EPA's Record Of Decision for the site, September 29, 1992, www.epa.gov/superfund/sites/rods/fulltext/r0592221.pdf; and the U.S. Census Web site, http://www.census.gov.

[2] See http://www.epa.gov/superfund/resources/remedy/pdf/540g-89006-s.pdf for information about ACLs.

As a result, in 1998 EPA produced an Explanation of Significant Differences (ESD) that modified the remedial decision from the 1992 ROD. In addition to a modification of certain capping requirements, the ESD revised the ACLs for ground water contaminants using ground water/surface water interface (GSI) criteria established by the Michigan Department of Environmental Quality, Surface Water Quality Division. Because these standards were developed, the "monitoring program used to measure compliance for the GSI numerical criteria would also replace the ROD requirement for surface water, river sediment, and biological monitoring". With this modification, the Michigan Department of Environmental Quality concurred with EPA's remedy. In addition, this approach saved $700,000 by eliminating the need to conduct the surface water, river sediment, and biological sampling, and by reducing the number of monitoring events needed to establish the ACLs.

The Butterworth #2 Landfill site remedy incorporates institutional controls (ICs)—administrative or legal controls placed on land parcels that help to minimize the potential for human exposure to contamination and/or protect the integrity of a remedy. The ICs were not specifically named in the 1992 Record of Decision, but rather were generally defined to include: "as necessary, restrictions to control future development of the landfill area and to prohibit the installation of ground-water drinking water supplies at the Butterworth Landfill property and an isolation zone" of land surrounding the site.

The Return to Use Initiative (RTU) is the latest phase of the Superfund Redevelopment Initiative. It facilitates Superfund site reuse by removing barriers that are not needed to protect human health, the environment, or the remedy. Butterworth Landfill #2 was the location of the national announcement of the RTU on November 10^{th}, 2004. At Butterworth Landfill #2, EPA Region 5 worked with the city of Grand Rapids to conduct a new risk assessment and approve removal of a portion of the fence surrounding the site so that two adjacent biking and hiking trails can be connected. Region 5 is also working with the city to open major portions of the site to recreational use in the near future.

Since the remedy results in hazardous substances remaining on the site above health-based levels, EPA will conduct recurring Five-Year Reviews to ensure that the remedy remains protective of human health and the environment. Operations and maintenance (O&M) activities will also continue; these activities include maintenance of the landfill cap and monitoring of the level of contaminants in ground water and surface water. The site's ground water will be monitored for a minimum of 30 years after the remedy's completion in 2000. Ground water monitoring may be extended beyond 30 years if EPA finds it necessary in order to protect human health and the environment.

The cleanup of the Butterworth #2 Landfill site, one of a cluster of Superfund sites in and around Grand Rapids, illustrates a typical approach to a landfill-type NPL site. It also illustrates EPA's commitment to working with states, as the original remedy was revised to accommodate Michigan's preferred ARARs. It also represents a good example of how EPA works with communities to allow them to return sites to productive use after cleanup. Finally, the site's cleanup demonstrates the importance of institutional controls and O&M activities at Superfund sites.

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